STUDY OF ELECTRIC RATES AND RATEMAKING

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CONTENTS.

Introduction . . . . 1.

Requirements of a Successful Rate System. 6.

Rate Forms and Their Characteristics . . 8.

Flat Rates . . . . 9.

Straight Meter Rates . . . . 10.

Demand Meter Rate . . . . 11.

Two Charge Rate . . . . 12.

Three Charge or Doherty Rate . . . . 16.

Factors Influencing Ratemaking . . . . . . 17.

Diversity Factor . . . . 19.

Demand Factor . . . . 25.

Basis of a System of Rates . . . . 27.

Municipally Operated Central Station . . 34.

Relation of Public Utility Commission

to the Rate Question . . . . 35.

Tables . . . . 40.

Bibliography.

STUDY OF ELECTRIC RATES
AND RATEMAKING.

The subject of Electric Rates has been studied in a great many different lights and has been discussed by a great many able men. Much space has been given to it in the trade journals and in the proceedings of engineering societies, and it is still a live subject of wide interest. The spread of the movement for regulation of public utilities and the consequent necessity for an equitable and scientific method of fixing rates, particularly for electric energy, gives additional importance to the subject. Accordingly, the authors have undertaken to make a general study of the subject, as it is presented in the trade journals and proceedings of engineering societies, primarily with a view toward increasing their own knowledge but hoping that they may be able to present an unbiased resumé of what

has been said and done in this field, for the benefit of others who may be interested.

Before any concrete examples are taken up, it will be well to consider the situation in general in order to obtain an insight into the conditions under which Central Stations operate and the nature of the problems with which ratemakers must deal. In the first place, the Central Station is engaged in producing electrical energy from coal, water-power or other source and in distributing and selling the energy produced to be used for a variety of purposes, by different classes of consumers. In this statement alone are involved enough variables to indicate the difficulty of making any generalization with regard to the selling price of energy that could be applied equitably to all cases; there are the wide differences in the cost of mach-

inery and labor required to produce the marketable product, in cost of distributing systems to deliver the product to the consumer, and in cost of equipment the company must install to take care of the demands of individual consumers and classes of consumers. Then there is the all-important distinction of electric energy supply and most other forms of public utilities that makes the subject of electric rates so troublesome, that is, the inability to economically store electric energy. Because of this fact, a Central Station must carry sufficient generating equipment, in working order, to supply the maximum demand of it's consumers at any instant, even though a large part of the equipment must lie idle for the greater part of the day, and some of it for a large part of the year. The fact that the maximum demands of the

various consumers do not come at the same time brings in the Diversity Factor of the system, one of the most important factors in making a system of rates which will insure a fair return on the investment and at the same time a fair division of the costs among the consumers. On the other hand, a system of rates, as presented to consumers who are not expected to study deeply into the subject, must be so easily understood that there will be no tendency to antagonize particular classes because of apparent discrimination, or to arouse unjust suspicion on account of indefiniteness.

In the early days of the Central Station business, the object of station managers was to charge what could be obtained for energy varying the rates whenever it was thought possible to get a higher rate or necessary to give a lower rate to get business. In other

words, they based their rates solely on "what the traffic would bear." Under conditions of free competition such a policy would be very likely to work out equitably to all concerned because the user would be able to choose and the seller would be obliged to keep his charges at cost plus a reasonable profit, or be obliged to quit because of working at a loss with many consumers or at a good profit per consumer but with too few consumers. However, the supply of electric energy is by nature a monopoly, i.e. the public receives better and cheaper service from a company properly conducted as a monopoly than under competition. This is obvious if we assume that in both cases a fair return on the investment is made. If a fair return on the investment isnot being made, conditions are unstable, and unsatisfactory service will result,

with the public the loser. Where a monopoly exists, a charge based solely on "what the traffic will bear" will manifestly lead to unfair conditions. However, it must be recognized that every practical rate system must be devised with considerable attention to this factor or it cannot meet the requirements of a successful rate system as enumerated in the next paragraph.

Requirements of a Successful Rate System.

Every student of the subject has put forth his opinion of what constitutes a successful rate system, in different forms and in different terms and it is attempted in what follows to make a statement of the requirements of a successful system that represents the consensus of opinion on the subject.

A successful rate system in its ultimate form must

(1.) Be fair and equitable to both consumer and producer, i.e. it must approximate, -(no practical rate could more than approximate)- the cost of the service and energy which the consumer uses plus a reasonable profit; and furnish a reasonable return on the investment.

(2.) Be equitable to all classes of consumers.

(3.) Be in a form simple enough for the public to understand and appreciate.

(4.) Provide for a healthy growth of the system. This last is an important factor, because no Central Station can afford to continue growing in a direction that will increase its expenses at a greater rate than its income. It must encourage the classes of load that increase its plant factor.

Rate Forms and Their Characteristics.

In the order of their development, the various general classes of rate forms and their characteristics will now be taken up. All of the rate systems discussed in the following table are subject to wholesale discounts and discounts for prompt payment. It has been found that the public has no difficulty in understanding wholesale discounts or discounts for prompt payment. When the latter , which amounts only to a provision for the extra expense incurred in the collection of late bills, is put in the form of a penalty to be added to the bills, it meets with much disfavor, and where tried has been discontinued.

Flat Rates.

The flat rate was the first system to be used because there were no satisfactory meters in the early days of the Central Station.
Under the flat rate system, rates were based on the connected load, number of lights, rating of motors, etc. The expense of meters was avoided, and simplicity of bookkeeping and billing were other good points. It failed to comply with good business principles since such a rate could not possibly be fair to the marketing of a commodity such as electric energy, where the cost is made up largely of service cost, the cost of the energy cost being often secondary. Furthermore, it does not promote economy in the use of energy by consumers, nor encourage the growth of the Central Station in the right direction.

The use of the flat rate is by no means obsolete, for they have their value in

dealing with certain classes of consumers, particularly for residence consumers in small towns and villages. Flat rates are valuable in building up the load on a high voltage network supplying a large number of small villages. They are most successfully used in connection with current-limiting devices. Many large Central Stations offer flat rates as optional rates in residences.

Straight Meter Rate.

When good meters became cheap enough to make their use general, the waste occasioned by flat rates was done away with by selling energy at a straight metered rate. This gave rise to a new evil because theconsumer often increased his connected load and consequently his maximum demand far in excess of the average on which the rate had been based. The Central Station suffered by having to

install extra generating capacity without an increase in their income.

Demand-Meter Rate.

The next advance was a decided step toward a rational basis of rates. A rate system based directly on the cost of supplying the individual consumer is the theoretically ideal system and any step in this direction is very likely to be in the right direction. Certain expenses, such as interest on investment, depreciation, etc., are closely dependent on the maximum demand on the station and hence on the maximum demand of the consumer, though the Diversity factor intervenes between the station maximum and the consumers maxima. It is evident, however, that the capacity of Central Station required will be a function of the consumers' maximum demands. This was recognized when the Demand-Meter rate

was introduced, in which the charge per kilowatt hour is based on the maximum demand of the consumers installation as measured by an indicating maximum - demand meter.

Two Charge Rate.

It must be borne in mind that those who first had the making of the rates to do, were bound by custom to make a rate that would be in a form familiar to the public in order that their efforts to sell their energy should not be met with suspicion because of a lack of understanding. For example, it would be extremely difficult to make the people who were accustomed to paying a definite price for their articles, whether bought by one or a dozen, to see that they should pay 12¢per kilowatt hour for the first 15 kilowatt-hours they used and then only 5 or 6 cents for the rest. This was the situation in the beginning of the

Central Station business. Hence it was by way of educational work that the first multiple rate systems were introduced in the form of the two-charge rate, in which part of the energy is charged for at a high rate based on the maximum demand and the lower rate applied to the remainder. Various types of meters have been used to indicate the maximum demand of an installation, the most widely used being the Wright demand-meter, which indicates the maximum demand directly in kilowatts and is used in connection with the usual integrating watthour meter. The instrument records only such peaks as last for an appreciable time, such as five to ten minutes, responding only slightly to short peaks. However, the use of such instruments for every consumer would mean a very serious addition to the already high meter investment

required for residence installations. As stated in another section of this paper, the meter investment for this class of consumers is often higher than the corresponding cost of station equipment. Accordingly, there is good reason for avoiding this expense and the tendency for some time back has been to use non-instrumental methods for getting at the small consumers' maximum demand. Some of the methods are:

(1.) Determining the demand from the connected load.

(2.) From the connected load, but omitting certain conveniences such as lamps in closets and out of the way corners.

(3.) From the connected load, but omitting desirable off-peak appliances suchas flat-irons, desk fans, etc.

(4.) The number of rooms in a house.

(5.) The area to be illuminated.

(6.) The valuation of the house.

The Commonwealth Edison Company of Chicago, after using the Wright demand-meter in a great many different classes of installations for a few years, has dispensed with the meters and use the average data obtained in each class of service for estimating the maximum demand. There is another advantage in the non-instrumental methods of estimating demand in that they encourage the use of appliances that help to fill in the valleys in the load curve and increase the diversity factor at the same time. The ordinary maximum-demand meter does not take into account the time of day at which the maximum occurs.

The Three-Charge or Doherty Rate.

In the three-charge system, the fixed charges are subdivided into a consumer charge depending only on the number of consumers, and a demand charge based on the consumers' maximum demand. In it's simple form this method probably comes nearer to paralleling the consumer's actual cost than any of the other simple rate forms described above. The Doherty system was brought out in 1900, and since then has found wide use in companies operating under very different conditions.

There has been considerable demand for standardization of rate forms throughout the country and the National Electric Light Association through it's Rate Research Committee has expressed itself as in favor of the movement and put forth a set of standard forms for the guidance of public utility commissions and

for the use of the member companies of the association. At present most of the large companies have different rate forms, many of them very well designed to give the necessary simplicity combined with a proper apportionment of the costs. It is obvious that almost any of the enumerated rate forms when combined with various quantity discounts, step rates, block rates, etc., in different degrees can be made to give the same general result as far as actual rates are concerned. It would serve to implant confidence were these various systems made uniform throughout the country since it would help to educate the public to the real status of the Central Station business.

FACTORS INFLUENCING RATEMAKING.

Before taking up these factors which are concerned with the maximum or peak load, something might be said as to the length of time duration of peak. The peak may be considered for any length of time as, momentary, one minute, five minute, 15 minute, hour, or, were we considering the year, one day might be considered the peak of the curve. The peak to be used under a given condition is variable. If the plant is a hydro-electric one, peaks of one minute are not too short to seriously overtax the plant if it is working well up to full load. On the other hand, an ordinary steam plant can easily carry an overload of 25% for an hour or 50% for 15 minutes without undue strain. Therefore a peak of short duration which is sufficient to severely overtax a hydro-electric station, has little

effect upon the steam plant. It is this fact coupled with the flexibility of location which enables a steam plant to undersell the hydro plant.

With the ordinary steam plant it is customary to take the peak as that indicated by the Wright maximum-demand meter for commercial lighting loads. The length of time of this peak varies somewhat with the size of the peak, but may be taken as approximately a 15 minute peak. For railway service, wattmeters which record their readings every half-hour or hour, by printing the reading upon a paper tape, are often used. For street lighting, the peak is the total connected load and extends over the time the lights are in operation.

DIVERSITY FACTOR.

Diversity factor, as defined by the standardization rules of the American Institute of Electrical Engineers, is the ratio of the sum of the maximum power demands of the sub-divisions of any system or parts of a system to the maximum demand of the whole system, or of the part of the system under consideration measured at the point of supply. Its definition might be stated as the ratio of the sum of the peaks to the peak of the sum, for any division of the system. Diversity factor as concerning the Central Station, may be between the Central and substation, between substation and feeders, between feeders and transformers, or between transformer and consumers. All of these Diversity factors influence the cost and size of equipment, and it is this which determines the fixed

charges. In the opinion of Mr. L. A. Ferguson of the American Institute of Electrical Engineers, "The Diversity factor is the very foundation rock of centralized energy supply. It is the birth-right of theCentral Station, the fundamental reason for its existance." It is one of the most important factors which enables a Central Station to install transmission lines, transformers and sub-stations, and still deliver power upon a consumer's premises at a charge less than the actual cost of generating the power upon the premises. Diversity factors vary with the type of load, the time of year, and the habits of the people. The society man burns his light in the evening, the milkman in the morning, and the same apparatus in the Central Station can generate both. This is only typical of the varying habits of the people,

which results in a large diversity factor, and a large saving in Central Station equipment.

Any attempt to give an average Diversity factor for any class of service is of little use, owing to thevariation of the habits of the people in different localities. However, in order to give some idea of how Diversity factors are computed and used in figuring the cost of delivering energy to a given point, two tables of Diversity factors are included in this article, and a third table to show how these factors effect the total investment per kilowatt of rated output for the examples given. These tables and the explanation of the same are taken from a report in the Electrical World (Vol. LVI,No.19) of a paper read by Mr. H. B. Gear at a meeting of the Association of Edison Illuminating Companies and is based upon determinations made for and

on the lines of the Commonwealth Edison Company of Chicago.

Group A (Table I) represents a residence block in which there are 34 consumers having a connected load of 18 kilowatts, or an average of .53 kilowatt per consumer. The sum of the consumers' maxima is 12 k.w., while the maximum as measured at the single transformer supplying this block is 3.6 k.w. The Diversity factor is thus 3.33 between the consumers in the block.

Group B is a similar block having 185 consumers and in Group C about two-thirds of the premises were small apartments and the remainder large apartments and residences. Demand indicators were used in determining the maxima.

Among the commercial lighting consumers, Group D represents small stores on an

outlying business street, with several saloons and restaurants. In Group E there are no large stores, saloons, or restaurants, Group F includes nine apartments above stores and an equal number of offices, lodge halls, etc.

Among the general motor users, Group H consists of 29 single phase motors having a connected load of 27 H.P. and an average load of 1.1 H.P. The sum of the consumers maxima is 30 k.v.a., the transformer maximum is 21 k.v.a. and the diversity factor 1.43. The consumers are "sweat shops", manufacturing mens' clothing.

Group I and K are small manufacturers. In Group J the largest consumer is a woodworking establishment in which the machinery operates steadily which accounts for the high transformer maximum and the low Diversity factor.

Table II gives various Diversity factors of the system.

Table III shows the total investment cost per k.w. of rated output for the different classes of service. These figures vary depending upon whether the consumers are close together or somewhat scattered. The figures given are computed, assuming the generating plant can be installed for $100 a k.w. of rated output, substation and transmission lines for $60 a k.w., feeders, mains, services, etc. at an average of $150 a k.w. and meters at $10 each.

Such business as refrigeration plants, bakeries, amusement parks and summer resorts, having their maximum demands occuring at different times from the residence lighting load, improve the Diversity factor of the Central Station and low rates are often made to secure this class of business, since it

requires practically no increase in generating equipment.

DEMAND FACTOR.

The demand factor is the ratio, expressed in percent, of a consumers maximum demand to his connected load. While the demand factor of the system determines the amount of equipment, it is of use in the determination of rates only when it is known for the different classes of service. A small residence installation will have a higher demand factor than a large residence, while stores will have a much higher factor than either. The Wisconsin Railroad Commission have carried on a most comprehensive investigation to determine the demand factor for various classes of consumers. It gives the demand factor as approximately 40% for residences, flat, rooming houses, and public

buildings; 55% for schools, churches and factories; 75% for stores, offices, banks and saloons; and 100% for electric signs, hallways, and street lamps.

The demand factor determines the probable maximum from the connected load, which latter is easily obtained,and is of use in determining the rates for installations without demand-meters. The maximum load is what determines the amount of fixed charges to be apportioned to the consumer.

The load factor is the ratio of the average load to the peak load during a specified interval of time. The larger the diversity factor, the longer will the station be operating near its maximum capacity, the higher the load factorand the greater the output and consequently the greater the return on the fixed costs.

BASIS OF A SYSTEM OF RATES.

While the forms of rate systems vary from company to company, and even from branch to branch of the same company, there is not so much variation in the basis of the various rate systems for there are three distinct bases that can be used for a system of rates. These are, first, what the traffic will bear; second, value of the service; and third, the cost of the service plus profit. Although in the past it has been given more attention than any other factor, very little can be said in favor of the first as a basis for a rate system. Its only worth lies in its usefulness in connection with the third system as an aid in building up the valleys in the load curve by offering inducements to off-peak consumers. It might be called the leaven in a system of rates which is necessary

for growth but which must be used sparingly. The "value of the service" theory bases its rates on what the service is worth to the consumer and is closely related to the first basis. Such a system of rates would have to vary with every change in the industrial conditions and with the prices of raw materials. It would be impracticable except in some very special cases.

the cost of service as a basis for a system of rates is in accordance with the best business principles and is conceded to be the only logical basis. To find the cost of the service is not a simple matter and volumes have been written and spoken on the methods to be used, since the principle has been in general use. A large part of the work of the public utility commissions has been along this very line, particularly

in evaluating the fixed capital investments of companies whose rates are under question with a view to determining the amount on which a return is to be allowed. There is such a great diversity of opinion as to what values should be taken into account and what weight shall be given to the various factors that are recognized, as to whether intangible assets such as "going value", franchises, etc., should be considered in making the valuation; and the available discussion on the subject is so largely disconnected and fragmentary, that the authors, in their inexperience, do not feel capable of analysing the situation and will limit their consideration of the subject to presenting part of a comparatively old outline made by Mr. H. L. Doherty before the Wisconsin Utility Commission. Any method of arriving at a valuation of a plant to be used in determining its permissible income

must necessarily be based largely on personal opinion. Mr. Doherty has long been among the foremost recognized authorities in Central Station work and it is for this reason that his method is given here. His own words are used;

"Strange as it may seem there is no well defined method of determining valuation. It is often assumed that the entire difference between the physical value of a quasi-public corporation and its stock and bond value is represented by its franchise. Quoting from the report of the N.E.L.A. Public Policy Committee, 'A public service property can have a value aside from both the physical property and the franchise property, which is represented by many factors, among which are (a) operating organization, (b) development of business, (c) advantageous supply contracts, (d) special, general, and technical knowledge of the business on the part of the operators and directors, and (e)good-will."

He enumerates certain elementary points, which, though they may be difficult to determine, must be determined if a fair valuation is to be made. These are:

1. How is valuation of property to be determined?
2. What allowance is to be made for ordinary depreciation?
3. What allowance is to be made for depreciation due to obsolescence caused by,
   (a) Outgrowth of apparatus before its useful life is realized?
   (b) Changes in the art?
4. What allowance is to be made for risks due to
   (a) Changes in the art which will render present investment valueless?
   (b) Development of new art which will render investment valueless?
   (c) Accidents?
5. What shall be considered as the expense for the interest on the money represented by the value of the plant?
6. What shall be allowed for profit?

"The operating company with which I am connected uses a certain method of computing the value of certain items of property and I recently had occasion to use this in the testimony given at a hearing on this problem. This method is as follows:

'Estimate of minimum value of Blank Company, computed on method used by Doherty Operating Co. and including no values for intangible assets, such as going concern, good-will, franchises, etc.

A. Real Estate.
B. Physical property(as per inventory at present or minimum value.)
C. Omissions, two percent.

D. Engineering and supervision, 5% of B and C.
E. Ordinary contingencies (not to cover omissions), 10% of B and C.
F. Legal expenses, while building.
G. Insurance risk while building;
    Public liability.
    Employees' liability.
    Fire liability.
H. Allowance for fact that property was built piecemeal, 10% of B,C, and D.
I. Interest while building, 6% of A,B,C,D,E,F,&G.
J. Excess value (based on average cost) of completed property in excess of value based on estimated time and cost of building, 10% of A,B,C,D,E,F,G,& I.
K. Cost of organizing company, printing records, engraving stock and bonds, and miscellaneous.
L. Working capital, stock accounts, unpaid bills.

M. Unbilled gas and current, 5/30 of electric and gas total physical value.

Necessary expenditures other than for physical property.

N. Expenses of operating organization prior to completion of plant.
O. Operating expenses in excess of earnings during development period.
P. Interest on investment in excess of earnings during development period, being one-half the interest for two years on A,B,C,D,E,F,G,J,& K, and 50% of L & M.
Q. Cost of developing business.

On page 353 of Vol.52, of the

Electrical World, will be found some comment

on these various items, explaining the reason for each. Mr. Doherty's ideas on the subject of valuations may not be one-hundred percent correct but they are valuable for the clearness of his statements and the absence of ungrounded assumptions.

Uniform systems of accounting are required by some of the public utility commissions and constitute a valuable aid to such commissions in their work in determining a fair rate for any particular company within their jurisdiction. When uniform accounting was first required by the commissions there were many complaints raised by small companies who claimed that it would mean a hardship on account of the increased bookkeeping expense. It was found, however, that it was really a blessing in disguise for many leaks were located and remedied that

went unnoticed because of the lax accounting methods.

MUNICIPALLY OPERATED CENTRAL STATIONS.

About eight or ten years ago when the agitation against "trusts" and corporations was at its height, there was considerable demand for municipal operation of public utilities, including Central Stations. A study of the statistics of the United States Bureau of Census shows that while the number of Central Stations municipally operated has increased since 1907, the rate of increase has not been as rapid as the increase in total number of stations, nor has the amount of energy sold by municipal stations increased in anything like the increase of total energy sold. This indicates that municipal operation has not proven satisfactory, the increase in the number of stations probably being ac-

counted for operated in places that could not support a privately owned plant.

RELATION OF PUBLIC UTILITY COMMISSIONS TO THE RATE QUESTION.

The public utility commission idea has lately become very popular throughout the country because of the success met with by the older commissions. Of the more important states now having commissions may be mentioned New York, New Jersey, Massachusetts, Wisconsin, Illinois, Maryland, California, and Ohio; a list that shows that the movement is country-wide. These commissions reflect the public tendency toward government regulation of industries that are monopolies by nature, and are doing good work in the direction of doing away with the unreasoning prejudice against large corporations merely on account of their

size. The organization and powers of the various commissions is much the same and the following outline of the organization of the Illinois Public Utility Commission is typical of all of them.

The various classes of utilities such as railways, gas companies, and electric stations are each under the supervision of a separate branch of the commission, headed by one of the five appointed commissioners. Each commissioner has his own assistants, all of whom will eventually come under the civil service rules, and he conducts hearings and issues orders subject to ratification by the commission as a whole. The term of the commissioners is six years, no more than two to be appointed in any one year. The commission appoints its own legal adviser and secretary.

The commission has power to prescribe the method of accounting to be used by utilities, to require monthly reports to the commission, and to say when a utility may issue stocks and bonds and other evidences of indebtedness. It has the power to make valuations and decide whether or not the rates and schedules are just and reasonable; and to regulate all relations between different companies operating public utilities. Complaints may be made by either citizens or companies and hearings and rehearings held if sufficient cause appears. Appeal from the decisions of the Commission may be taken to the Circuit Court, Sangamon County, and from there to the Supreme Court.

It is interesting to note that after a year of operation the commission has had but one of its decisions reversed by the courts and that one on a technicality having to do

with the records of hearings.

That a properly conducted commission acts as a stabilizer for the utilities and has a beneficial effect on the relations between utilities and the public is clearly indicated by the powers invested in the commissions, and this indication has been fully borne out in the experience of those states having such commissions. The greatest difficulties of the commissions have been in the making of valuations, as might be expected. It is to be hoped that the joint efforts of the state commissions and the Interstate Commerce Commission will result in a standardization of the methods used in this important work and the standardization of accounting systems is certainly a step in the right direction.

There is little doubt that the future of the rate question lies with the

state utility commissions and the direction of their development to date would seem to indicate that they are quite capable of doing justice to all concerned.

TABLE I.

Analysis of Consumers Diversity Factors.

Group	Number of Consumers	K.W. connected per Consumer	Sum of Consumers Maxima	Maximum of the group	Diversity Factor
RESIDENCE LIGHTING.					
A	34	.53	12	3.6	3.33
B	185	.53	68	20	3.40
C	167	.87	93	28	3.32
Average	128	.68	57	17.2	3.35
COMMERCIAL LIGHTING.					
D	46	1.28	46	33	1.40
E	79	.74	36	26	1.40
F	160	.53	62	41	1.51
Average	95	.70	48	33	1.46
GENERAL MOTOR SERVICE.					
H	29	1.1 h.p.	30 kva.	21 kva.	1.43
I	18	3.3	40	25	1.60
J	11	11.8	90	65	1.39
K	25	6	100	70	1.43
Average	21	4.5	65	45	1.44

TABLE II.

Diversity-factors of the System.

	Residence lighting	Commercial lighting	Motor service	Large users
Between Consumers	3.35	1.46	1.44	——
Between Transformers	1.3	1.3	1.35	1.15
Between feeders	1.15	1.15	1.15	1.15
Between Substations	1.1	1.1	1.1	1.0
Consumer to Trans.	3.35	1.46	1.44	——
" " feeder	4.36	1.90	1.95	1.15
" " Substa.	5.02	2.19	2.24	1.32
" " Generator	5.52	2.41	2.46	1.45
" " " corrected for losses	4.13	1.81	1.84	1.09

TABLE III.

Investment in $ per K.W. for Various Consumers.

	Residence lighting	Commercial lighting	Motor service	Large users
Meters	124	38	15	——
Transformers	12	12	12	8
Distributing lines	146	146	145	49
Substation & Trans.	58	58	58	58
Generating equipment	100	100	100	100
Total investment	440	354	330	215

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Diversity Factors. - H. B. Gear pp.1115,1212.
pp.1479.

Demand and Diversity Factors and their Influence on Rates. - Cravath. p. 567.

Active Lamp "Readiness to Serve" Charge. p.1528.

Electrical World. Vol. 57.

Complex Charge p.1048.

Flat Rates. pp. 520, 1343, 788.

Municipal Plants and Rate Systems. p.61.

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Municipal Ownership and Rates. p. 1345.

Depreciation. pp.323,636,454,757,455,506.

Flat Rates for Small Consumers. p.46.

Easily Understood Statement of Rates. p.1142.

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Average Rates in 36 Large American Cities. p. 595.

Limiting Device for Flat Rates. pp.699, 1446.

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Theory of Tariffs. pp. 271, 1056, 1107.

Solution of the Rate Problem. p. 516.

Charging for Electric Energy- Boston. p.720.

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What the Service Will Bear. p.325.

Value of the Service Theory. p. 1277.

Rate-Making for Central Stations. p. 848.

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Regulation and Municipal Operation. p. 809.

Jurisdiction of Public Utility Commissions. p. 1415.

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